national accelerator laboratory FERMILAB-Conf-74/73-THY/EXP
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An Introduction to Fermilab*

MARTIN B. EINHORN
Fermi National Accelerator Laboratory, Batavia, Illinois 60510

ABSTRACT

Following an illustrated description of the Laboratory's natural site and resources, we describe the accelerator, its characteristics, and its performance record to date. We discuss briefly each of the four experimental areas: Internal Target Area, Neutrino Area, Proton Area, and Meson Laboratory. Beams available to each area are indicated. Experiments which are underway, as being set up, or have recently been completed are mentioned.

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June 12-18, 1974

In the following, we present a brief illustrated tour of Fermilab. This brief talk serves as an introduction to the companion lecture[1], "A Review of Some Recent Experimental Results from Fermilab," which follows in these Proceedings.

Located thirty-five miles west of downtown Chicago (Fig. 1), The Fermi National Accelerator Laboratory is located in a rural area which, however, is rapidly developing into residential housing. The Laboratory is located on a 6800 acre (28 km^2) site (Fig. 2) which, if not a laboratory forever, hopefully will be eternally preserved from suburbanization. Since we have not had the opportunity to entertain most of you in Illinois, let me begin by showing you some of the resources available to us on the site.

In Fig. 3, you see some of our most famous residents, Great American Buffalos. A herd originally of 17, it has now grown to number 36. With the recent donation to the Laboratory of a small herd of Scottish Longhorn Cattle (Fig. 4), we have moved even further toward becoming a minor zoo. In addition, the site has become a wildlife refuge, with innumerable ponds and lakes on which a great variety of ducks and geese may be seen (Fig. 5). One lake has been stocked and has become popular for fishing. In one of the old barns, the riding club keeps a number of horses. There is a wonderful collection of native trees which contributes to the natural beauty of the site. With a view toward the future, thousands more trees are planted each year.

Let me show you some of the architecture of interest around the Lab. In the dead center of the ring sits the surveyor's tower surrounded by the outlines of a logo (Fig. 6). In collaboration with the Morton Arboretum nearby, a new project has begun to restore the inner area of the main ring to natural Illinois prairie grasses, in which the buffalo may eventually roam.

The building in which the 15-foot Bubble Chamber was constructed is topped by a geodesic dome (Fig. 7), constructed of fiberglass panels sandwiched arouhd a honeycomb of soft drink cans. The multicolored roof thus formed is quite striking at night when the lights are on inside the building. Nearby is a pumping station (Fig. 8) whose stairway entrance is an Archimedian spiral.

Until recently, the laboratory personnel worked in many small houses, which were originally a private housing development taken over by the Laboratory when the land was transferred (Fig. 9). Now that we have moved into a new building, these are being converted back into housing to accommodate the many scientists who visit Fermilab each year. In the foreground of Fig. 9, you see a number of old farmhouses. Originally scattered about the site, they were moved to their present locations and preserved with new roofs and painted. They are also being fashioned into housing for visitors.

The architectural pride of Fermilab is the new 16-story Central Laboratory (Fig. 10) where nearly all personnel work. This elegant structure is quite an attraction. On a clear day one can see from the top many of the taller skyscrapers of downtown Chicago 60 kilometers away. The building is really two separate halves connected at the ends on the higher floors. The ends are glass (Fig. 11), as is the roof, enclosing a huge atrium where, like in a greenhouse, olive and fig trees and flowers grow (Fig. 12). This also has the advantage of exposing interior offices to exterior light and a pleasant view.

I believe the preceding overview suggests to you that, in addition, to being a huge machine, Fermilab is people coupling their creativity in research with the creation of a cultural community and the preservation of our natural habitat. Having realized this perspective, let us now take a brief tour of the accelerator as experienced by a proton.

In a giant Cockcroft-Walton "pre-accelerator" (Fig. 13), the protons are stripped from hydrogen and acceleratored through a series of potential steps to an energy of 750 kev. From the Cockcroft-Walton, the protons enter the Linac (Fig. 14), a 150-meter long linear accelerator which raises their energy to 200 MeV. From here, they enter the booster synchrotron, which not too long ago would have been considered quite a machine on its own merits (Fig. 15). With a diameter of about 150 meters, the booster raises the protons up to 8 GeV and then, at a frequency typically of 13 times per second, kicks them into the main ring. The main ring, a large alternating gradient proton

synchrotron with a radius of 1 km, accelerates the protons to an energy of between 200 and 400 GeV. It can be seen in Fig. 15 and also as the large circle in the aerial view in Fig. 2.

The evolution of the energy and intensity of the machine is indicated in the next figure (Fig. 16). As you can see, the machine has operated as high as 400 GeV/c. With the successful installation of a storage capacity recently, higher energies, perhaps in the neighborhood of 500 GeV/c, should be achieved over the coming year. The number of pulses per minute depends on the peak energy at which the accelerator is operating (typically, one pulse every 5 or 6 seconds). The peak intensity so far achieved has been 10^{13} protons per pulse obtained at 300 GeV on April 17 of this year. We anticipate the intensity will also increase during the next year.

From the Main Ring, protons are extracted and sent to three external experimental areas which are numbered on the aerial view of Fig. 17: The Proton Area (2), the Meson Laboratory (3) and the Neutrino Area (4). In addition, experiments are performed in the tunnel of the Main Ring at the Internal Target Area (1). Let me briefly outline the physics going on in each area.

One of the great advantages of the Internal Target is the ability to study proton interactions from as low an energy as 20 GeV to the highest energy available. At the Internal Target, the primary activity has centered around the use of the hydrogen jet (Fig. 18) brought to

Fermilab from Serpukhov and operated by a joint U.S.-U.S.S.R. collaboration. Several beautiful results on proton-proton elastic scattering (Exp. No. 36) have already been reported, such as the slope of the diffraction peak[2] (Fig. 19) and the ratio of the real to imaginary part[3] (Fig. 20). In addition, proton-deuteron elastic and inelastic scattering (Exp. No. 186) has been studied and will be returned to later.

Other experiments utilizing the hydrogen jet include inelastic pp scattering (Exp. No. 188) and the production of photons at large transverse momentum (Exp. No. 63), the latter also using a carbon target. In addition, there have been particle searches (Exp. No. 184) and inelastic pp scattering (Exp. No. 221) done in the ITA using targets other than the jet.

In the future, the ITA will be enlarged to make room for more apparatus to enable experimenters to achieve better resolution.

Following the protons out of the main ring, we move out of the Transfer Hall into the beam switchyard. (See Fig. 21 for the subsequent discussion). If we are essentially undeflected, we may find ourselves in the 30" Bubble Chamber which was moved here from Argonne National Laboratory. You are well aware of the results of many of the analysis pictures taken in this facility, and because of the existence of a comprehensive review by J. Whitmore,[4] I will not discuss this here. I would mention, however, that this now functions as a hybrid facility, as

spark chambers have been installed behind the chamber. We might also wind up in the 15' Bubble Chamber which just underwent its first engineering run (Exp. No. 234) and will establish itself as a major laboratory facility over the next year.

Another alternative for the protons is to strike one of several target loads, leading to a number of secondary beams listed in Fig. 22. There are 2 secondary hadron beams available, one for the 30" Bubble Chamber, and one for the 15' Chamber. There are two neutrino beam lines, one a broad band neutrino beam which will be used by the 15-fott chamber and has been used by Exp. No. 1A in their study of neutrino total cross sections, deep inelastic neutrino scattering, and neutral currents. The other neutrino beam is a dichromatic beam, centered about the two energies appropriate for the forward decays of momentum selected pions and kaons. This has been used by Exp. 21 in their study of neutrino interactions. Both these experiments have been discussed by Perkins at this meeting and will not be discussed further here.

Finally, the fifth beam available in the Neutrino Area (NA) is the muon beam, with a maximum intensity in the neighborhood of 10^6 muons per pulse of 10^{13} protons. The muon beam can be established at several momenta up to 150 GeV/c. Two experiments [Exp. No. 26 and Exp. No. 98] are using this beam to study electromagnetic interactions and are discussed in Ref. 1.

Had the protons been bent to the east (Fig. 21), we would have followed them into the Proton Area (PA) where several experiments are underway. The proton laboratory is a collection of holes in the ground, each of which houses an experiment. (Figure 23). I report results of two of these experiments [Exp. 70 and Exp. 100] in Ref. 1. Another (Exp. No. 87A) which is turning up, utilizes a photon beam still under development. Later, a polarized photon beam will also be available.

Had we followed protons to the West, we would have found ourselves in the Meson Area (MA). From the meson target hall, six beams emerge. Characteristics of these beams are given in Fig. 24 and will not be described further. There are a dozen hadron experiments underway in the Meson Laboratory, some of which will be discussed below. They include the determination of total cross sections, measurements of elastic scattering, pion charge exchange, single particle inclusive reactions, etc.

The characteristic features of each area described above are summarized in Fig. (25) and experiments which are being set up, taking data, or undergoing data analysis are listed in Fig. (26). A more complete list, including some completed experiments, is given in Fig. (27).

This completes our survey of the laboratory. For a discussion of some recent experimental results, see the companion lecture (Ref. 1) which follows.

REFERENCES

[1]M. B. Einhorn, Fermilab-Conf-74/74-THY/EXP, July 1974.

[2]V. Bartenev et al., Phys. Rev. Letters 31, 1088 (1973).

[3]Ibid., 31, 1367 (1973).

[4]J. Whitmore, NAL-Pub-73/70-EXP, December 1973 (submitted to Physics Reports.)

FIGURE CAPTIONS

Fig. 1 Map of Chicago area showing location of Fermilab.

Fig. 2 Aerial view of site.

Fig. 3 Three buffalo.

Fig. 4 Two Scottish Longhorn Cattle.

Fig. 5 Some ducks on Lake DUSAF.

Fig. 6 Surveyor's station in center of ring.

Fig. 7 Geodesic dome.

Fig. 8 Archimedian spiral stairway

Fig. 9 Weston village in background; farmhouses in foreground.

Fig. 10 Side view of Central Laboratory.

Fig. 11 Front view of Central Laboratory on Dedication Day, May 11, 1974.

Fig. 12 Interior of Central Lab.

Fig. 13 Cockcroft-Walton.

Fig. 14 Linac.

Fig. 15 Aerial view of booster and Main Ring.

Fig. 16 Chart of accelerator performance in terms of peak energy and flux.

Fig. 17 Aerial of experimental areas.

Fig. 18 Hydrogen jet installed in Internal Target.

Fig. 19 Slope of diffraction peak in pp elastic scattering (Ref. 2).

Fig. 20 Ratio of real to imaginary part of pp elastic scattering amplitude (Ref. 3).

Fig. 21 Schematic of accelerator and external experimental areas.

Fig. 22 Some features of Neutrino Area beams.

Fig. 23 One of proton pits under construction.

Fig. 24 Current characteristics of Meson Area beams.

Fig. 25 Summary of the four Experimental Areas.

Fig. 26 Location of experiments by Area.

Fig. 27 List of experiments completed or under way.

The figures above are a shortened selection from the color slides shown at the symposium. Many of them do not reproduce well in black and white and were omitted here.

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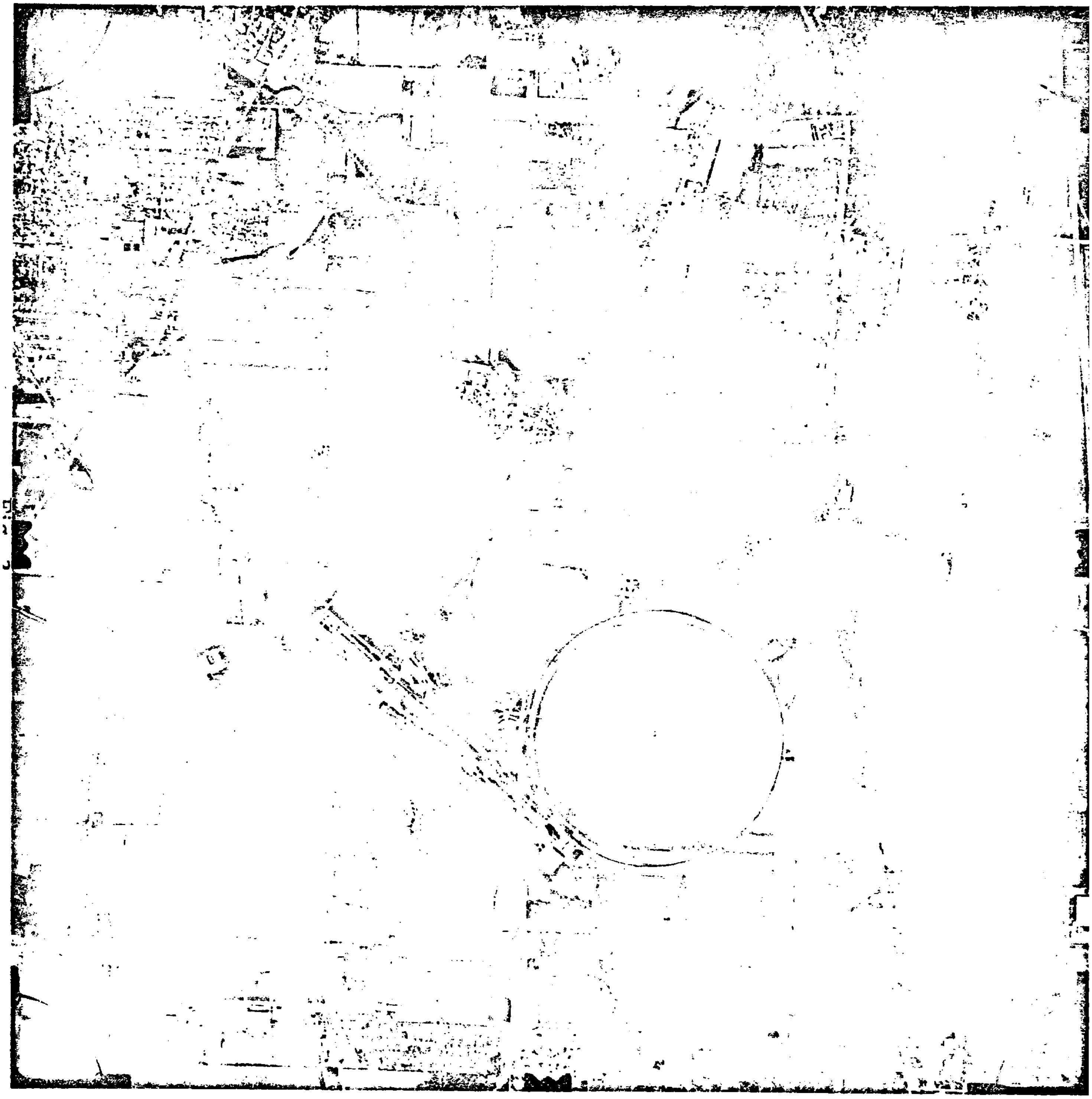

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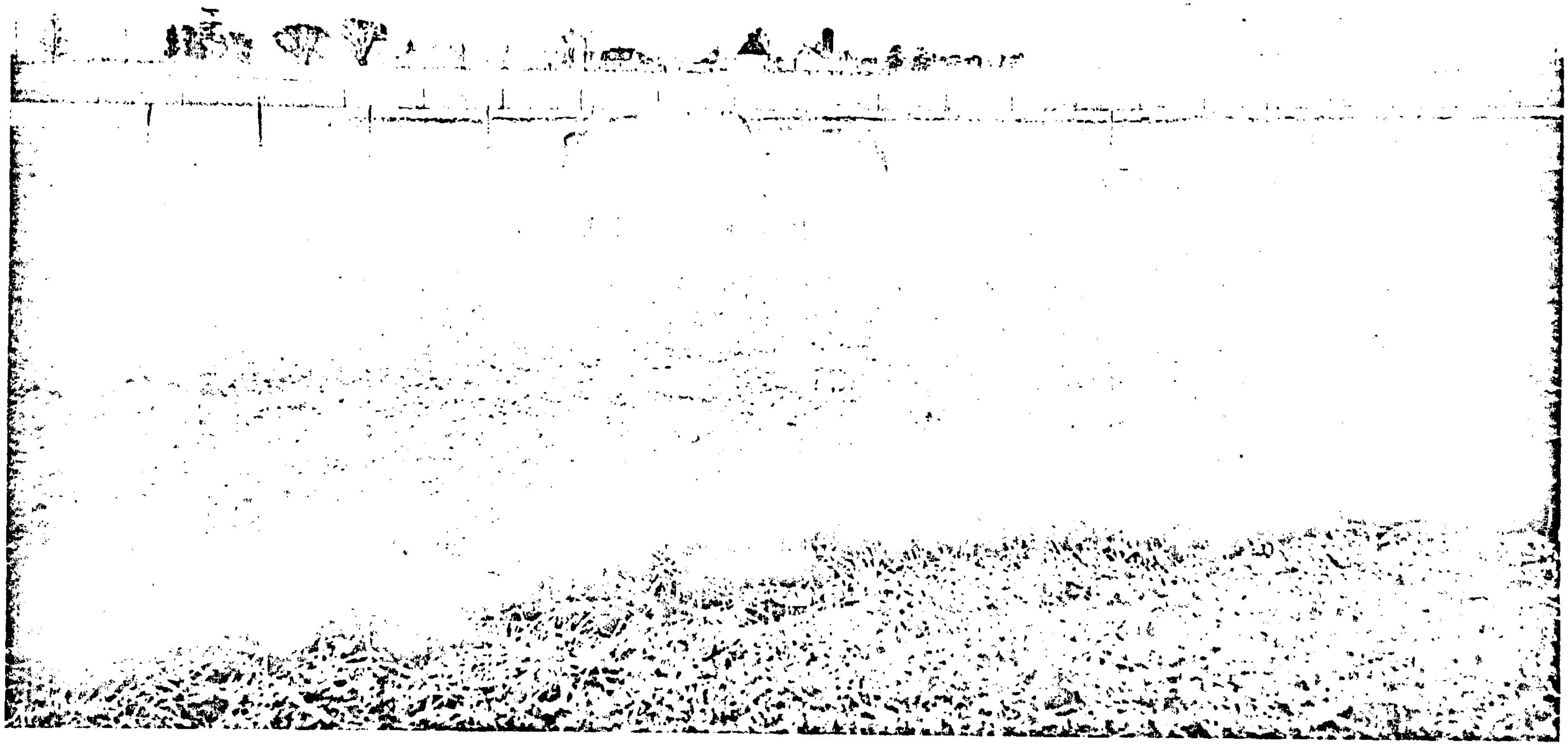

Fig. 3

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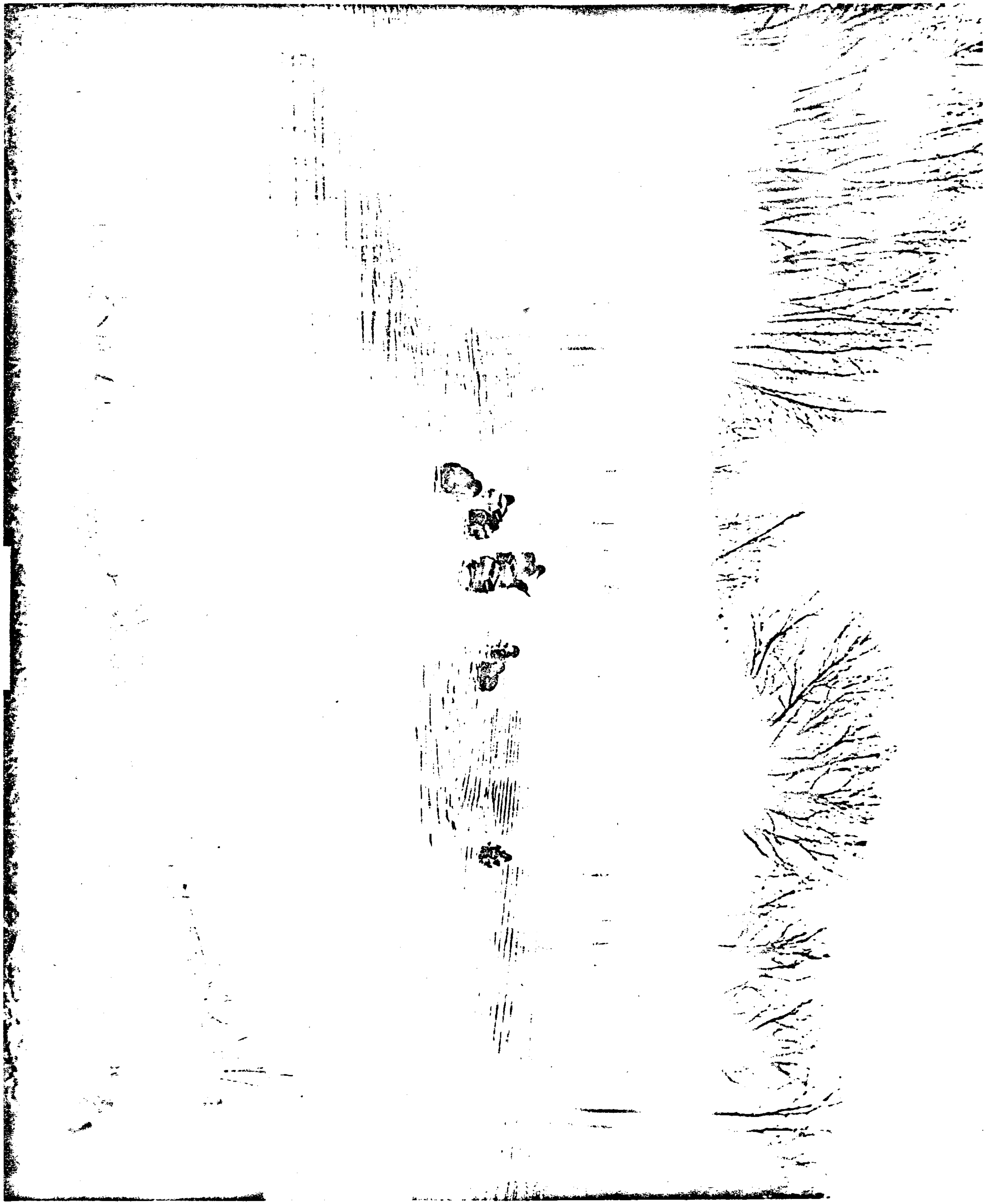


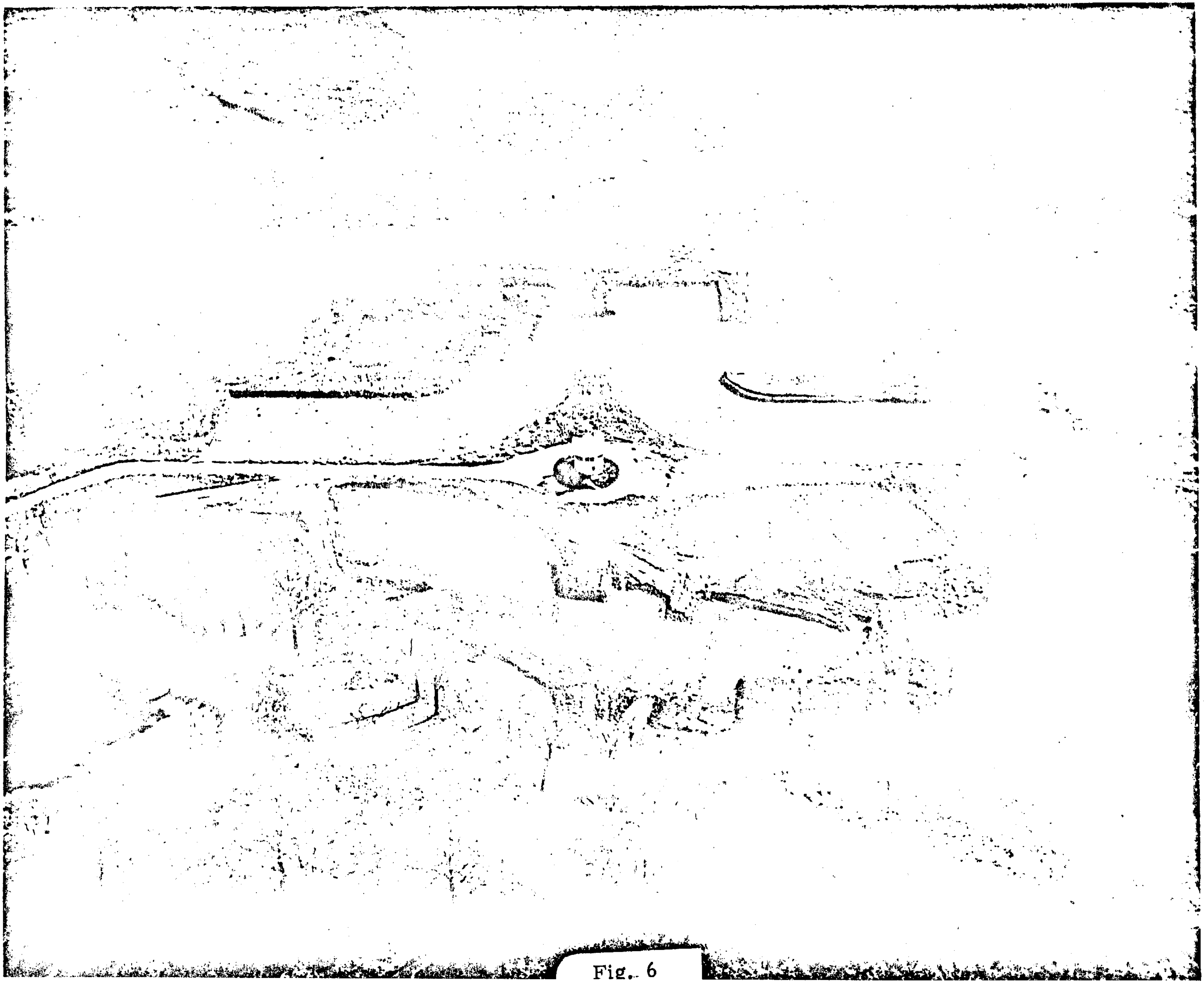


Fig. 6

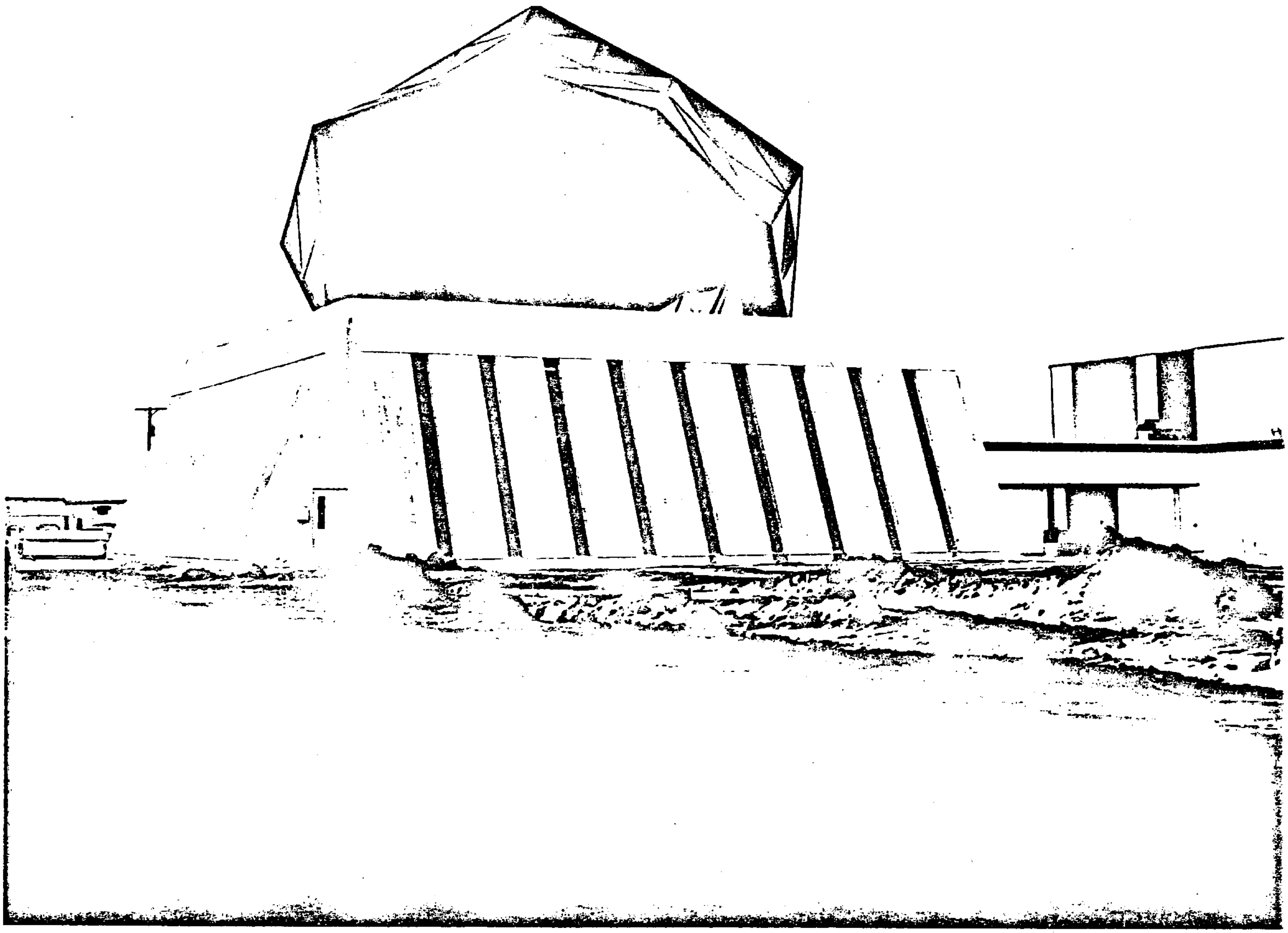


Fig. 7

Fig. 8

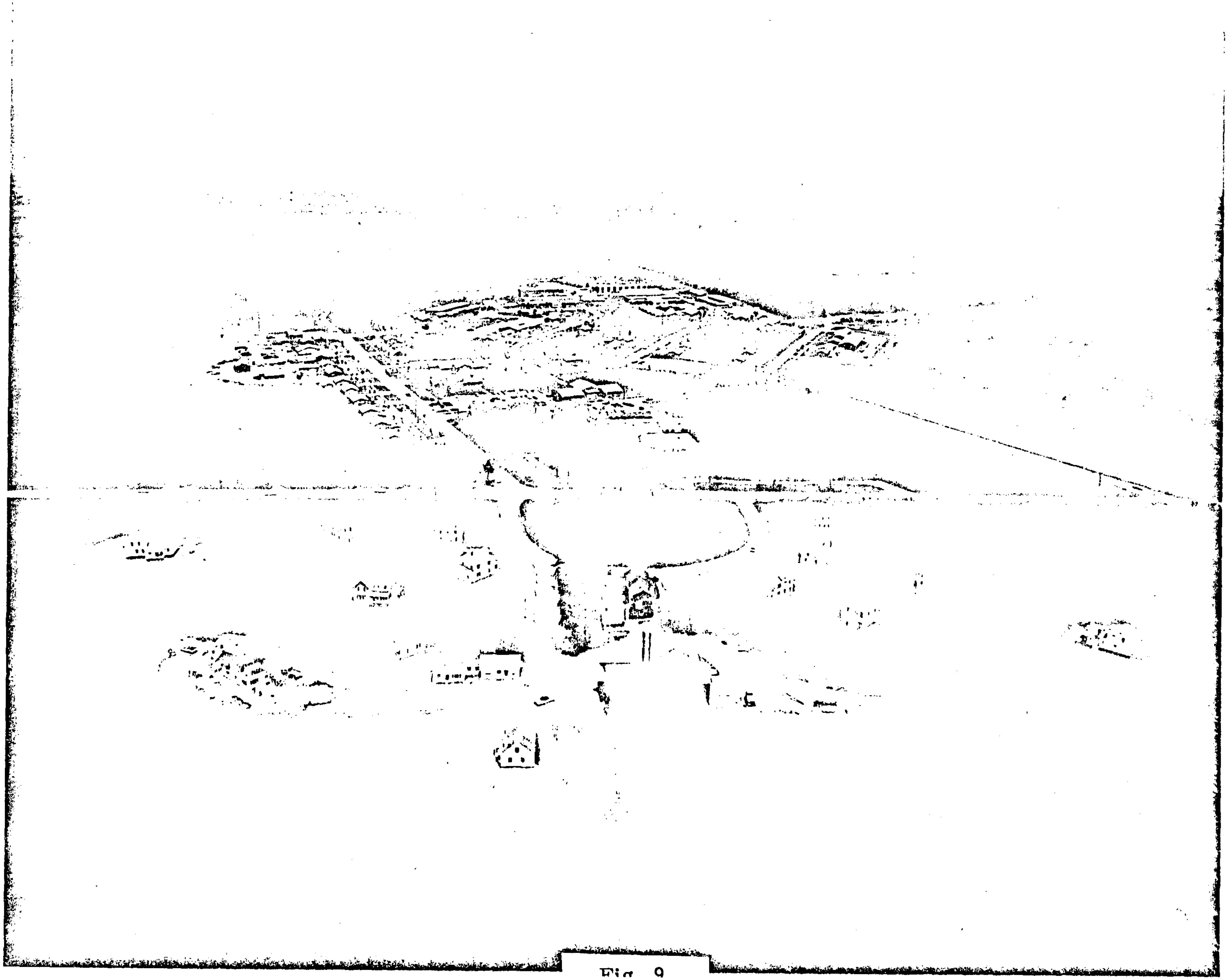


Fig. 9

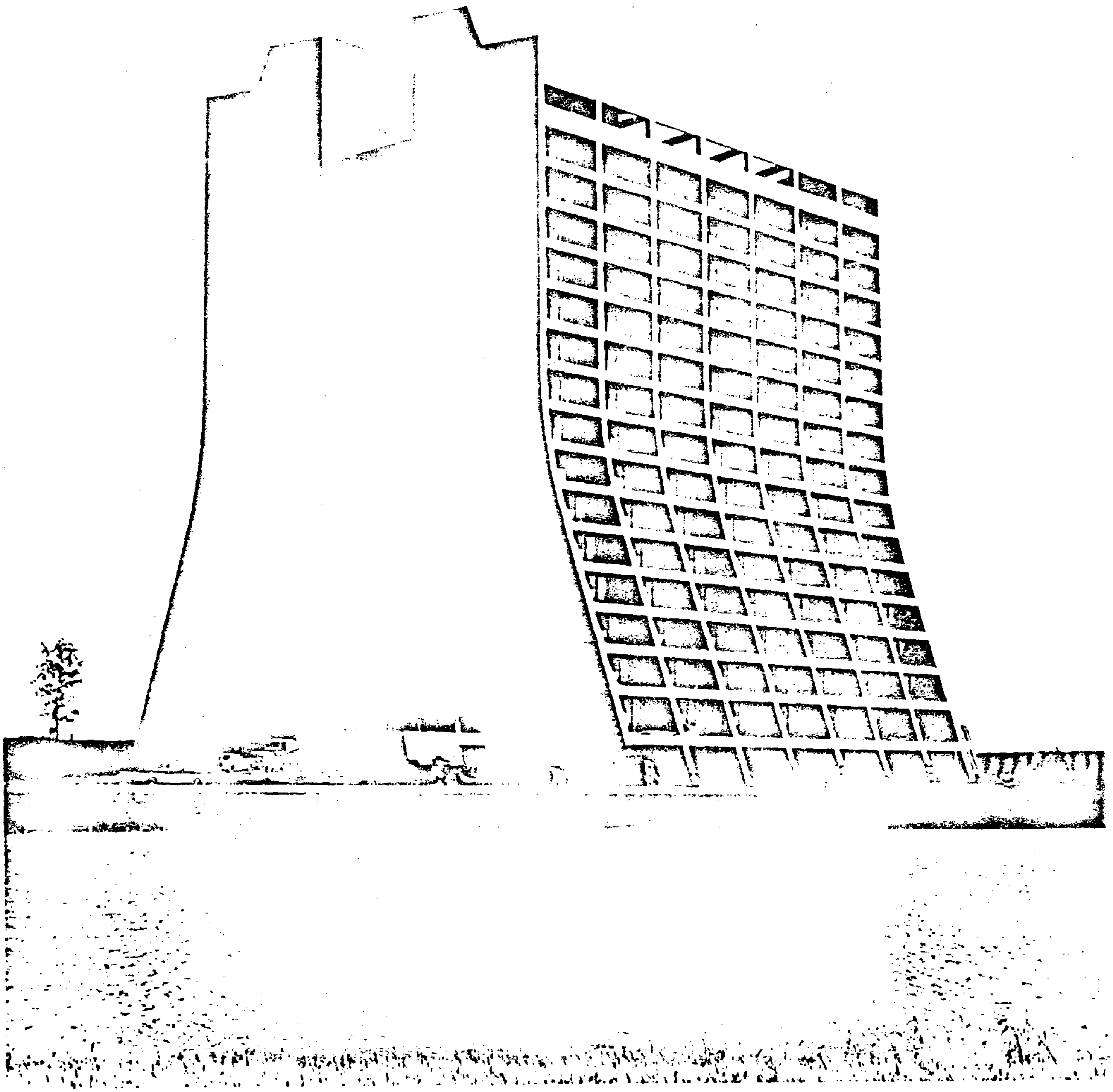
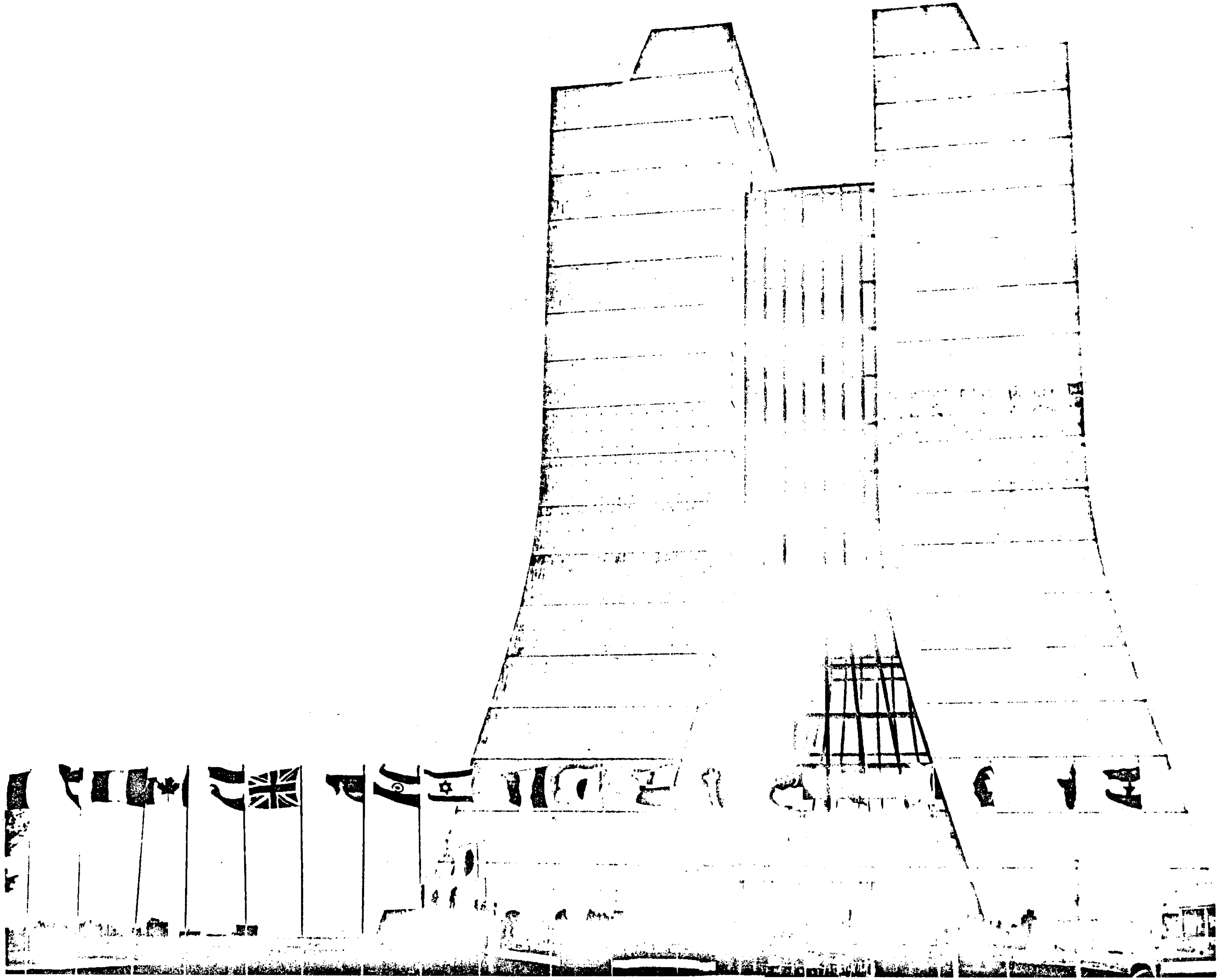


Fig. 10



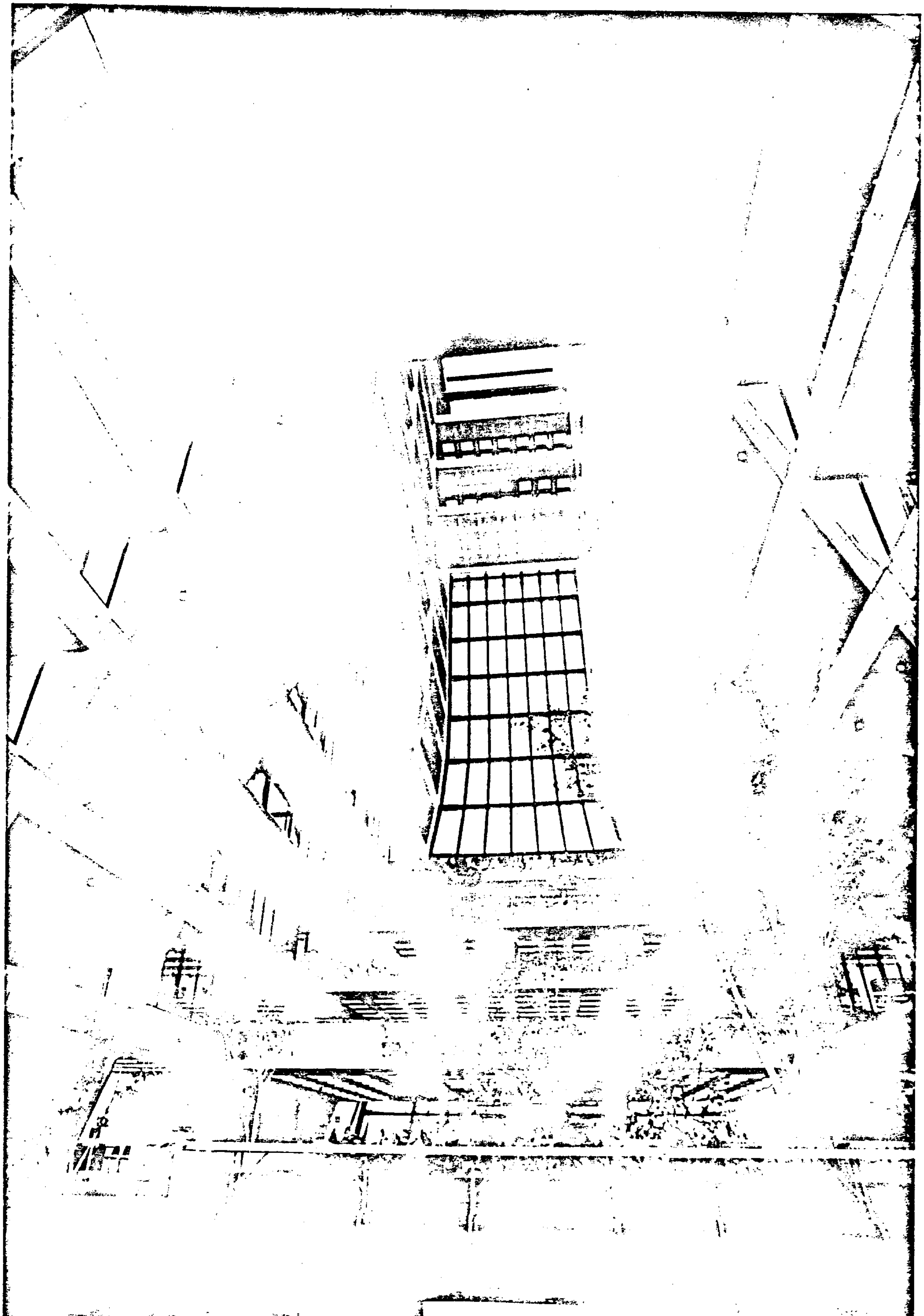


Fig. 12

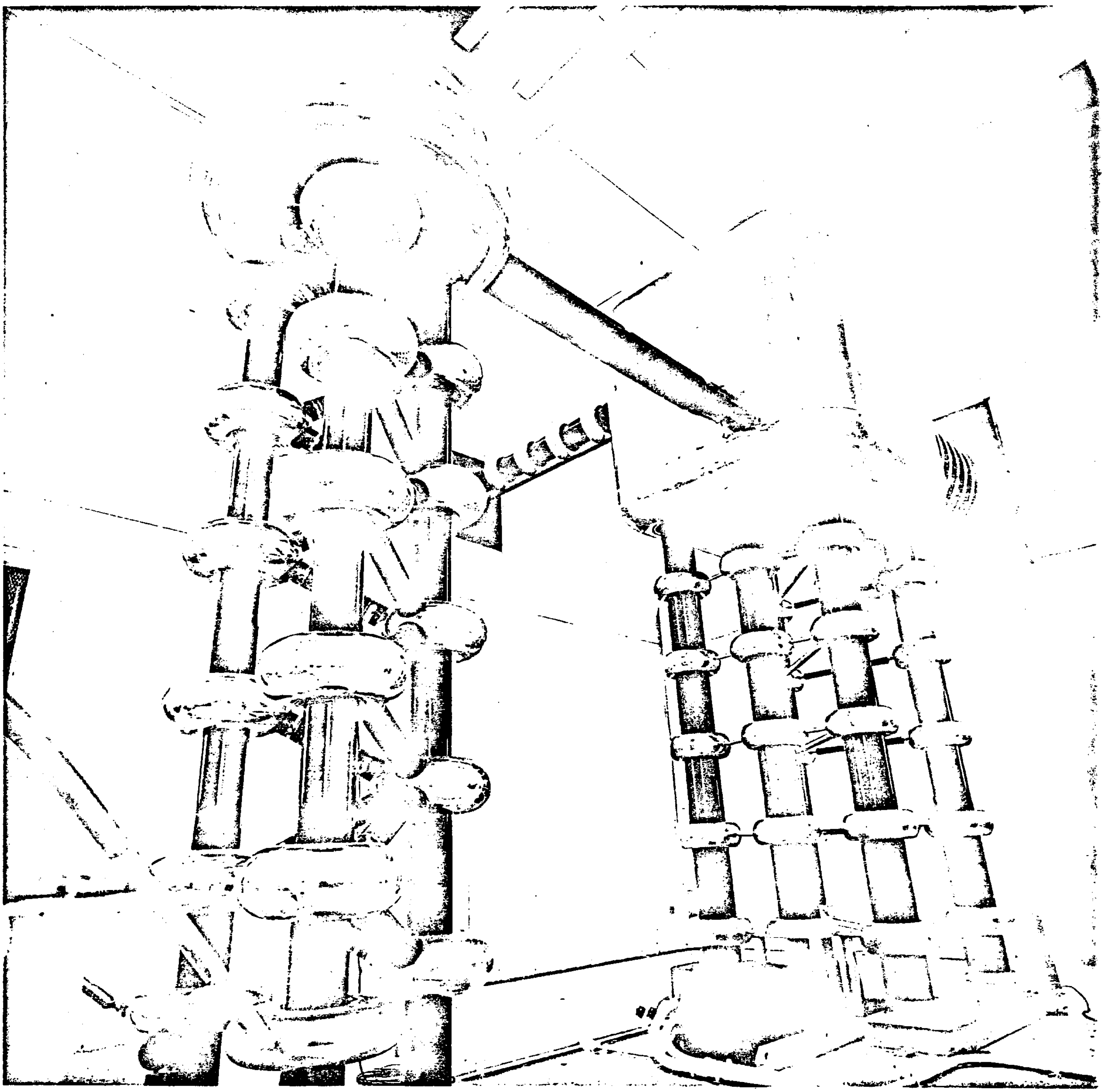


Fig. 13

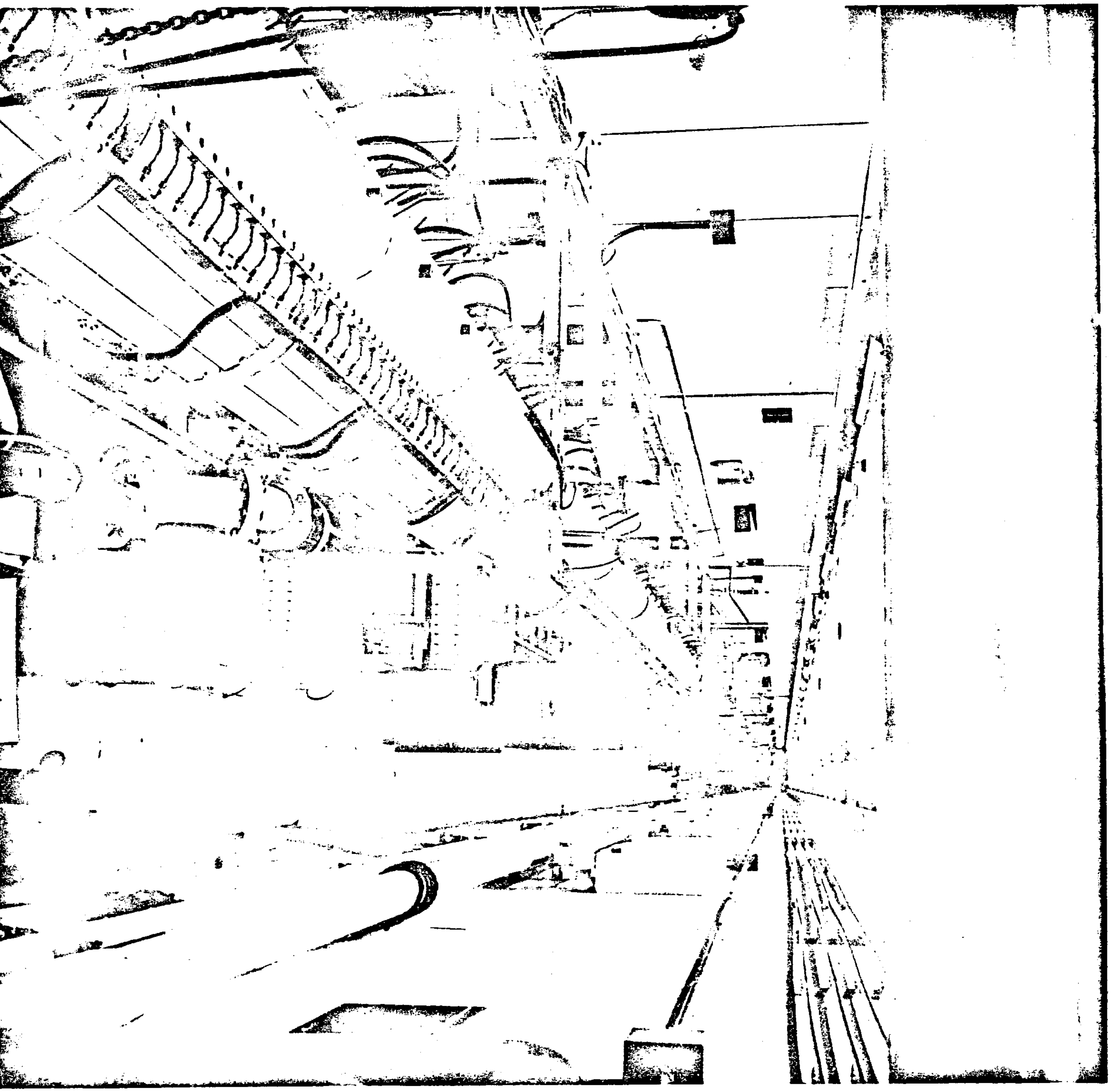


Fig. 14

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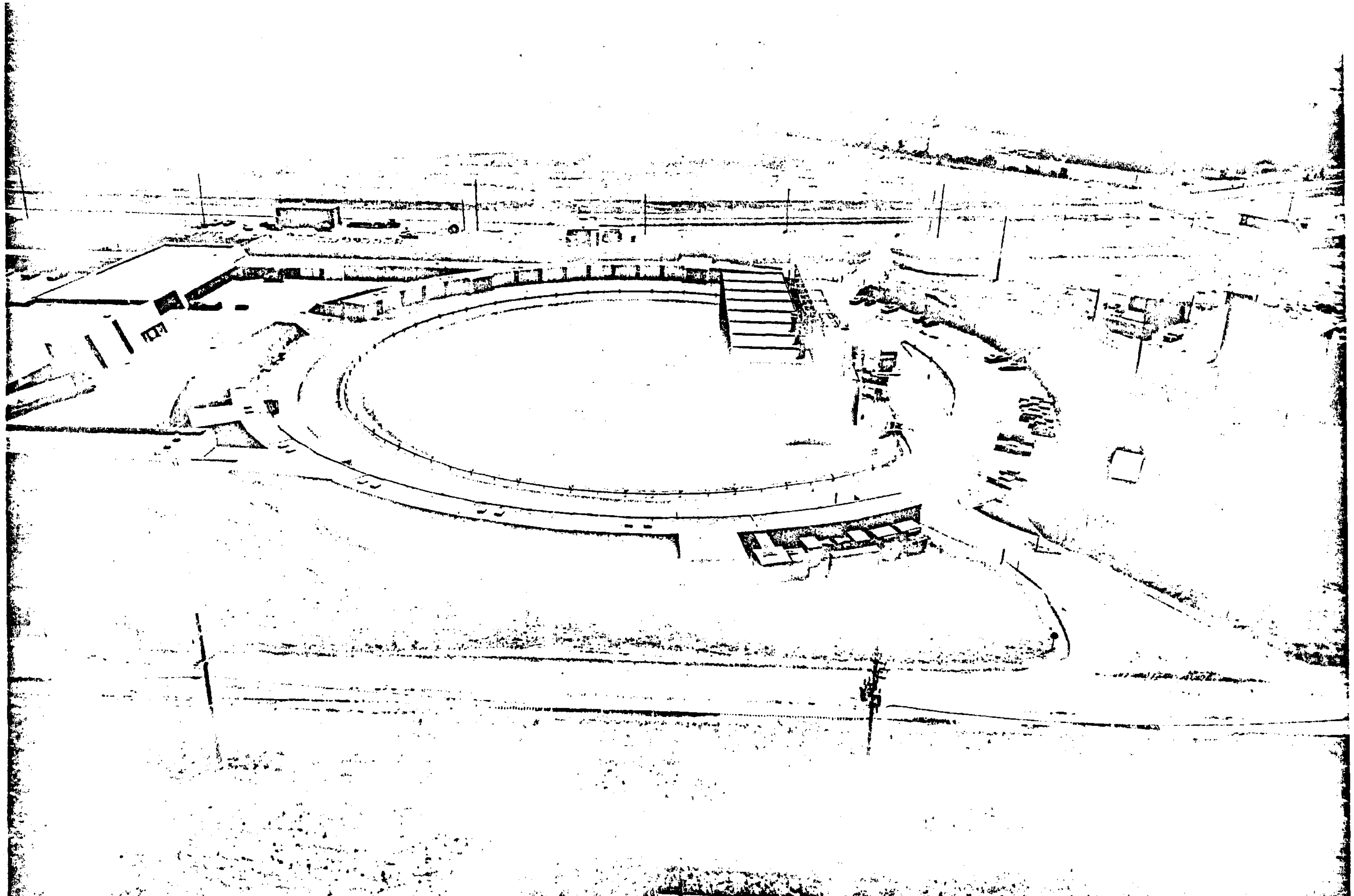


Fig. 15

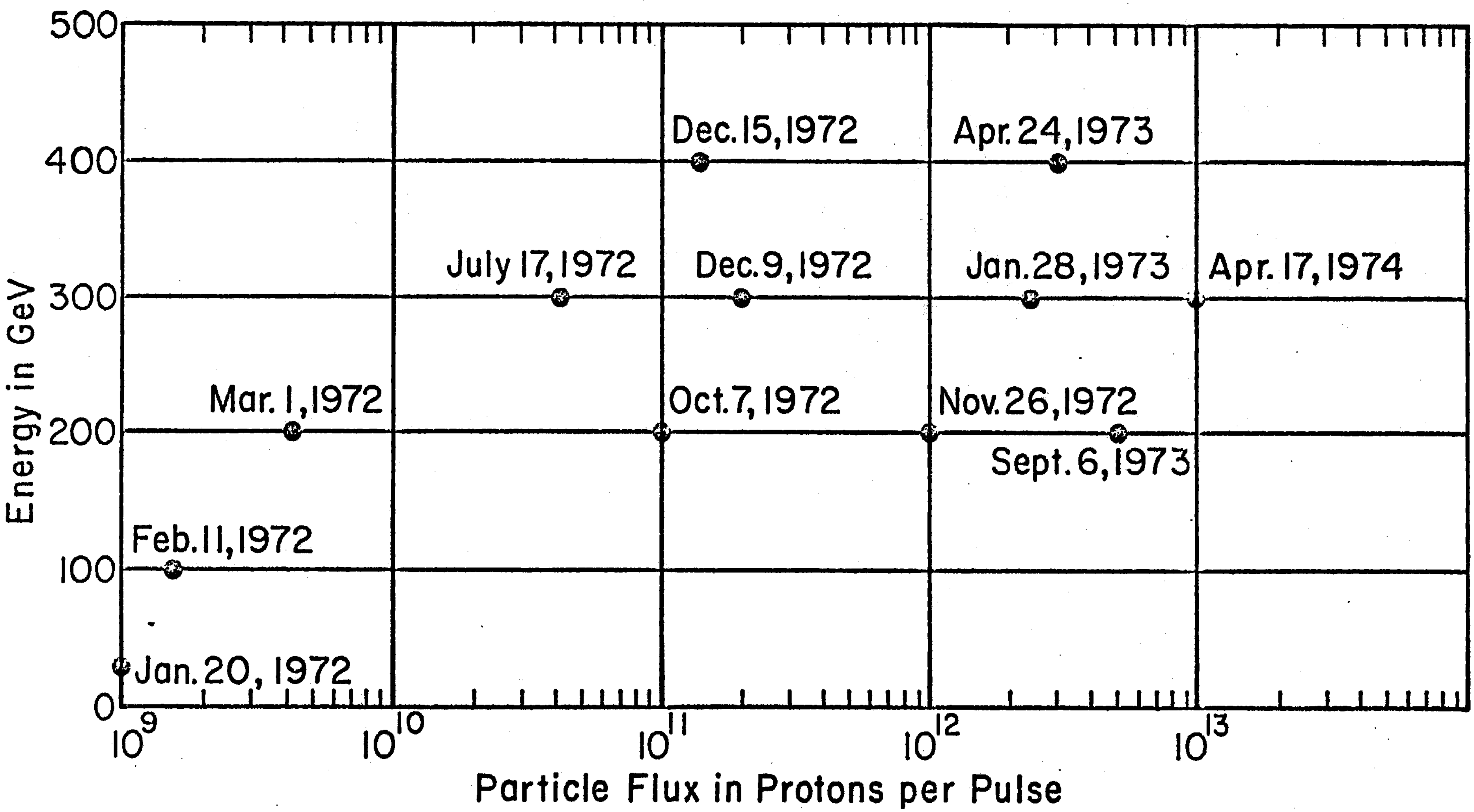

Energy in GeV
500
400
300
200
100
0
Dec.15,1972
Apr.24,1973
July 17,1972
Dec.9,1972
Jan.28,1973
Apr.17,1974
Mar.1,1972
Oct.7,1972
Nov.26,1972
Sept.6,1973
Feb.11,1972
Jan.20,1972
10^9
10^{10}
10^{11}
10^{12}
10^{13}
Particle Flux in Protons per Pulse

Fig. 16

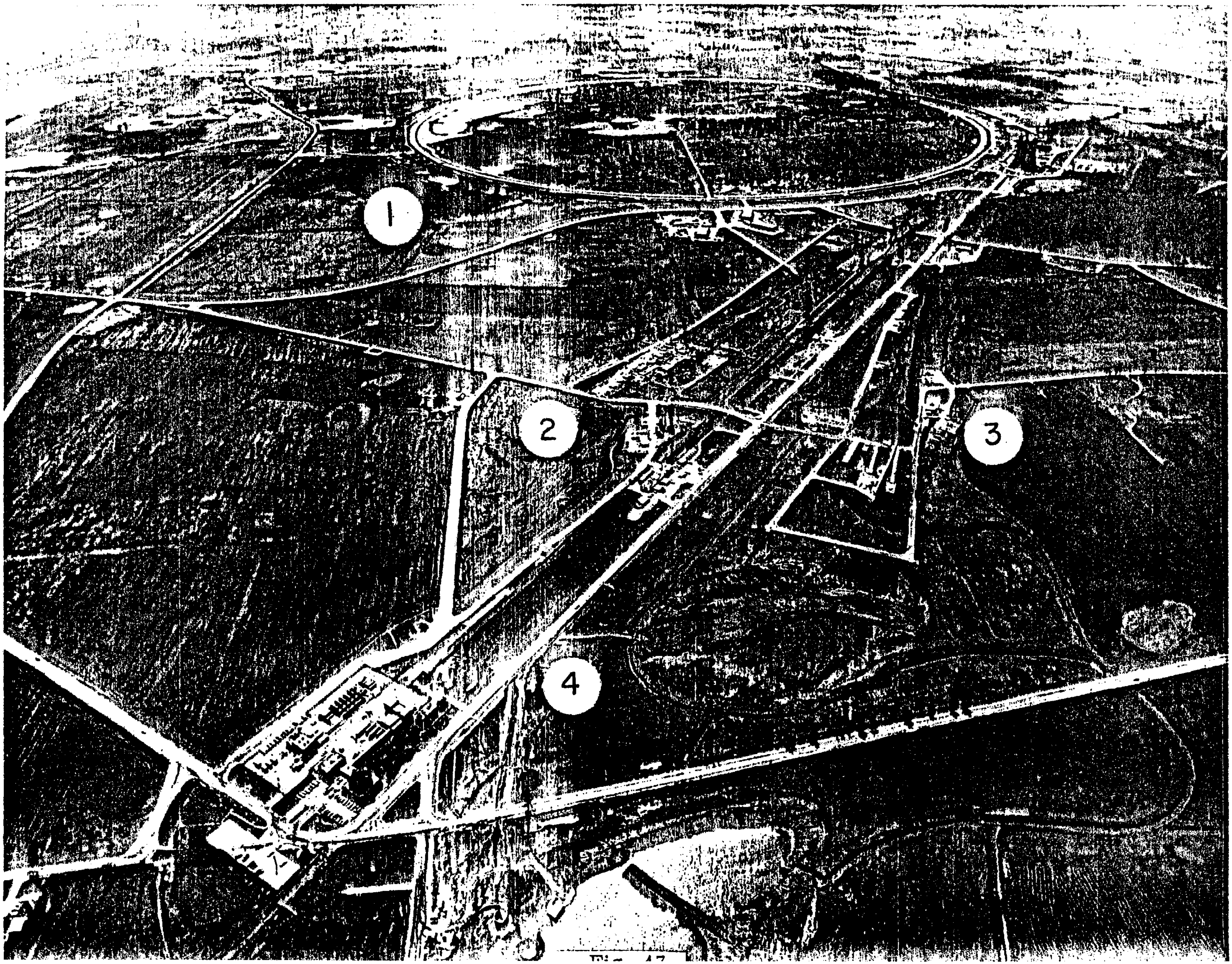


Fig. 17

Diagram of NAL's jet target, designed and built in the Soviet Union and brought to Batavia for use in Proton-Proton Elastic # 36.

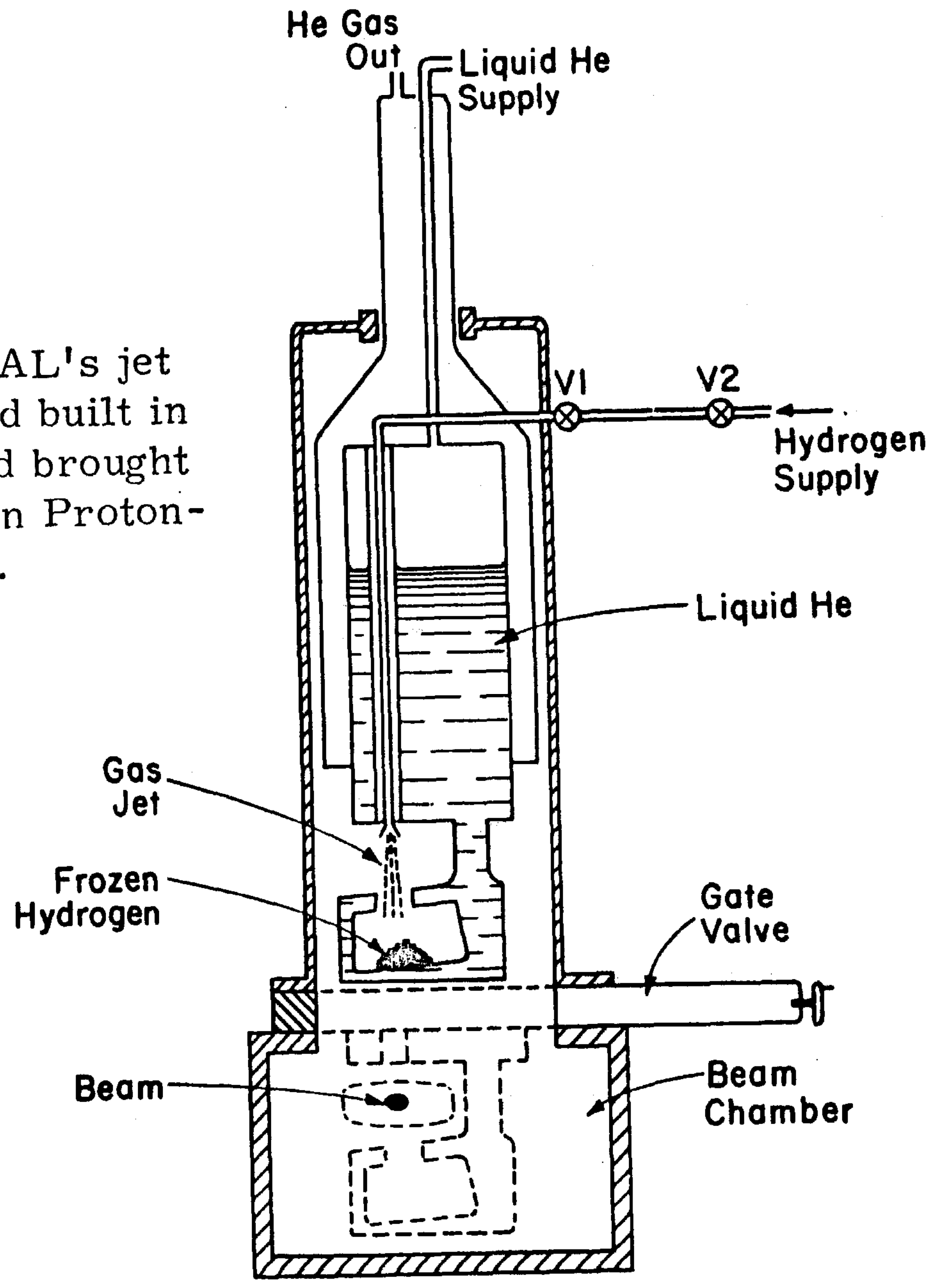
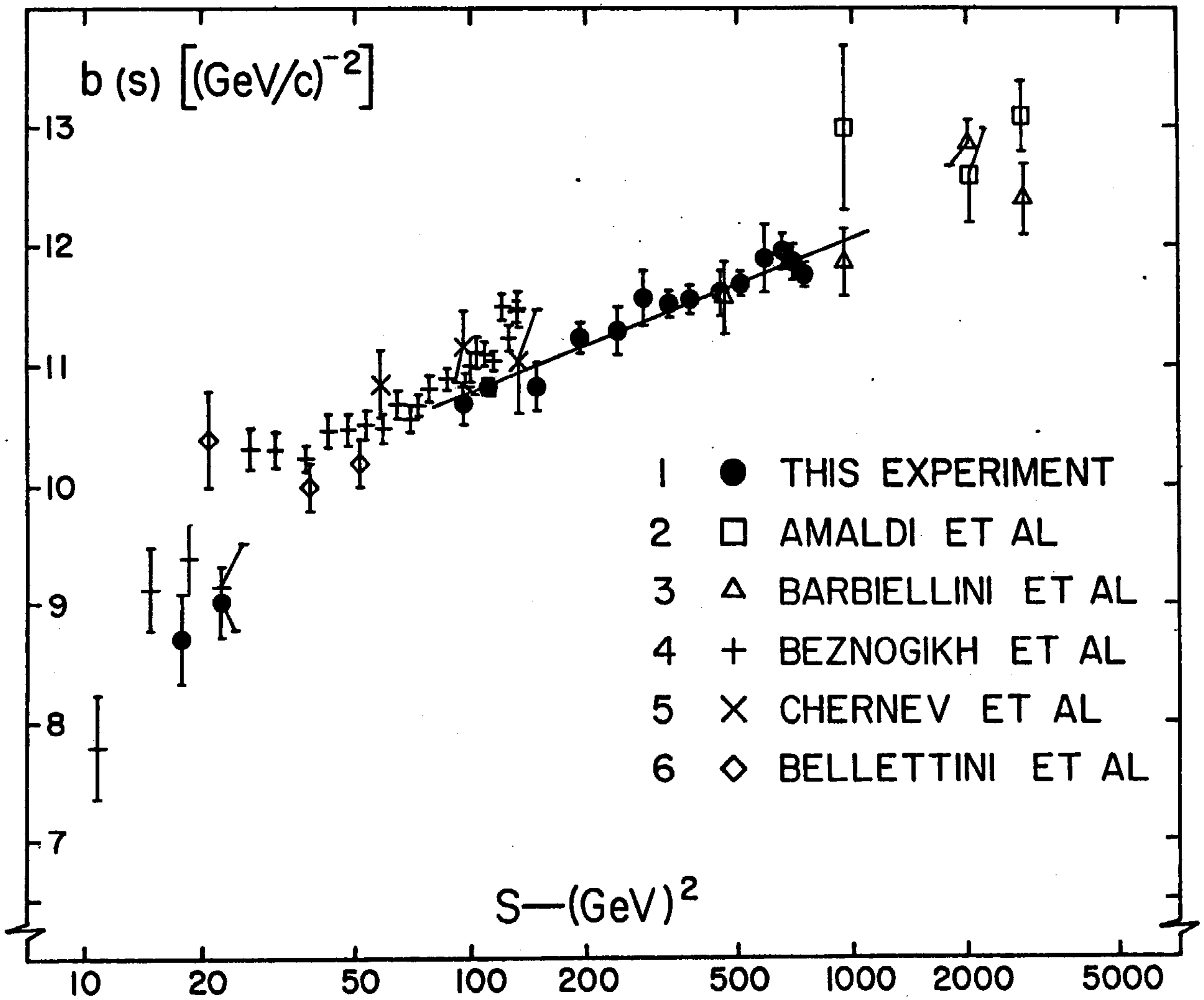


Fig. 18



b (s) [(GeV/c)$^{-2}$]
13
12
11
10
9
8
7
S—(GeV)^2
10
20
50
100
200
500
1000
2000
5000
1 ● THIS EXPERIMENT
2 □ AMALDI ET AL
3 △ BARBIELLINI ET AL
4 + BEZNOGIKH ET AL
5 × CHERNEV ET AL
6 ◇ BELLETTINI ET AL

Fig. 19

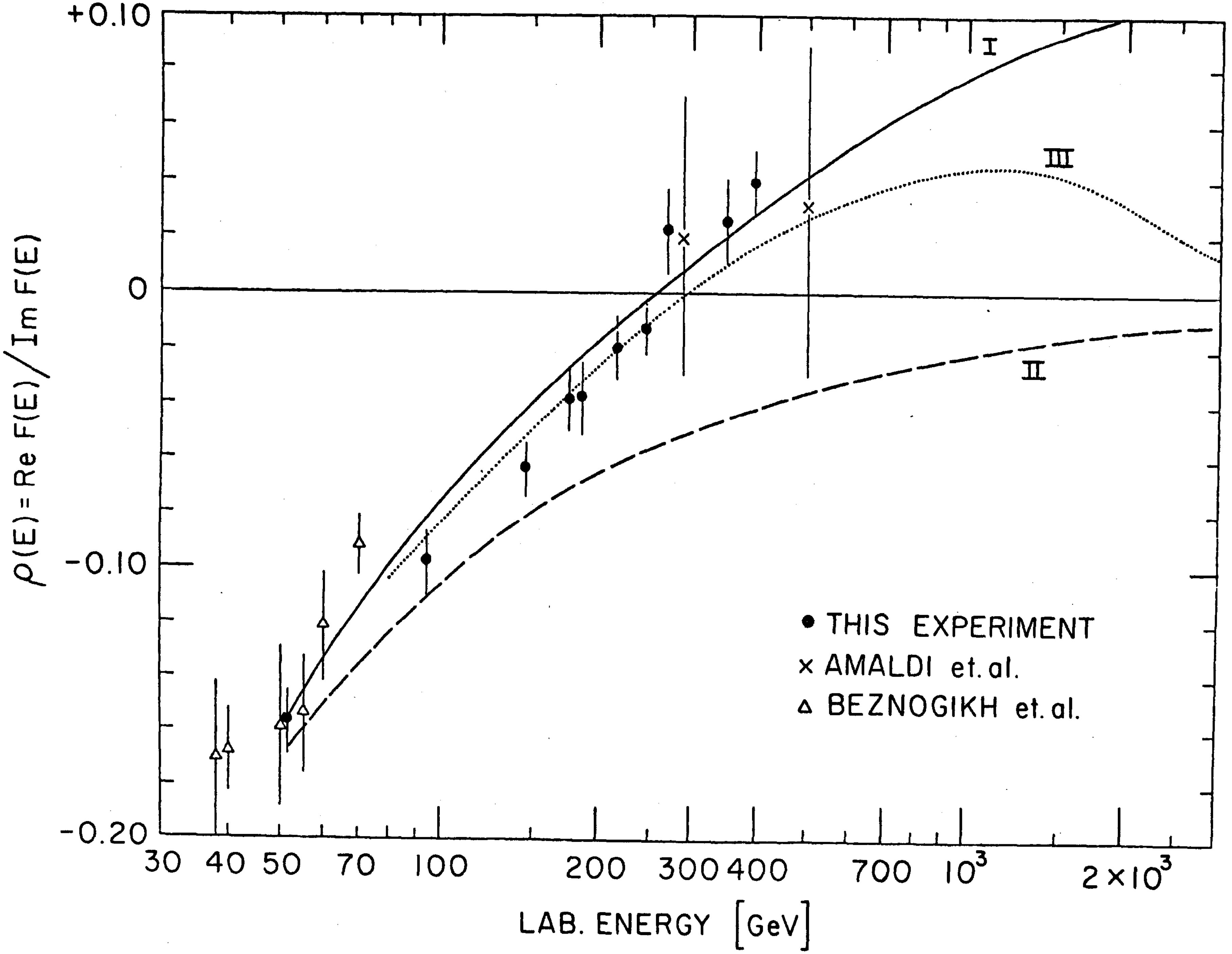

+0.10
0
-0.10
-0.20
$\rho(E) = \text{Re}\,F(E) / \text{Im}\,F(E)$
30
40
50
70
100
200
300
400
700
10^3
2×10^3
LAB. ENERGY [GeV]
I
II
III
● THIS EXPERIMENT
× AMALDI et. al.
△ BEZNOGIKH et. al.

Fig. 20

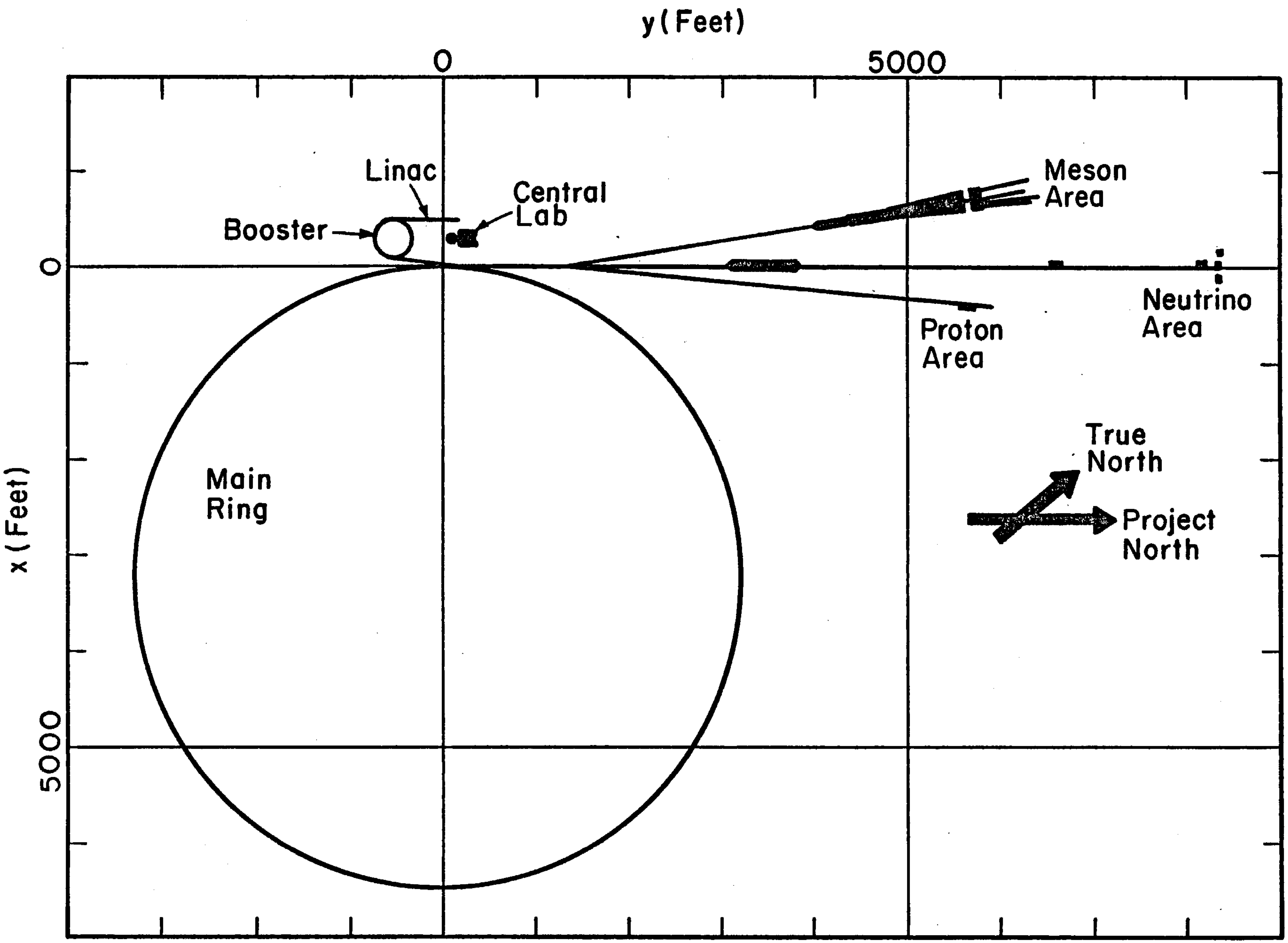

y (Feet)
0
5000
x (Feet)
0
5000
Linac
Central
Lab
Booster
Meson
Area
Neutrino
Area
Proton
Area
Main
Ring
True
North
Project
North

Fig. 21

Neutrino Area Beams

Beam	Production Angle mrad	Maximum Momentum GeV/c	Solid Angle μ sr	Momentum Acceptance $\Delta p/p$	Approx. Fluxpeak 10^{13} Interactin Protons at 300
NO-1 Quadrupole Narrow Band Neutrino Beam	0	300	4-16	± 5%	10^6 Neutrino through $1 m^2$
NO-2 Broad Band Horn Focus Neutrino Beam	0	500	2800	5-500 GeV	10^{10} Neutrino through 15' BC Spectrum Peak at 20 GeV
N1 Muon Beam	0	300		± 2%	10^6 μ^+ at 150 GeV/c
N3 Hadron Beam for 30" BC	Variable $0 \le p_T \le 1$ GeV/c	500	0.3	±.07% → ± 1.2 %	Sufficient for Bubble Chamber
N5 Hadron Beam for 15' BC	Variable $0 \le p_T \le 1$ GeV/c	500	0.3	±.02% → ± 0.6 %	Sufficient for Bubble Chamber

Fig. 22

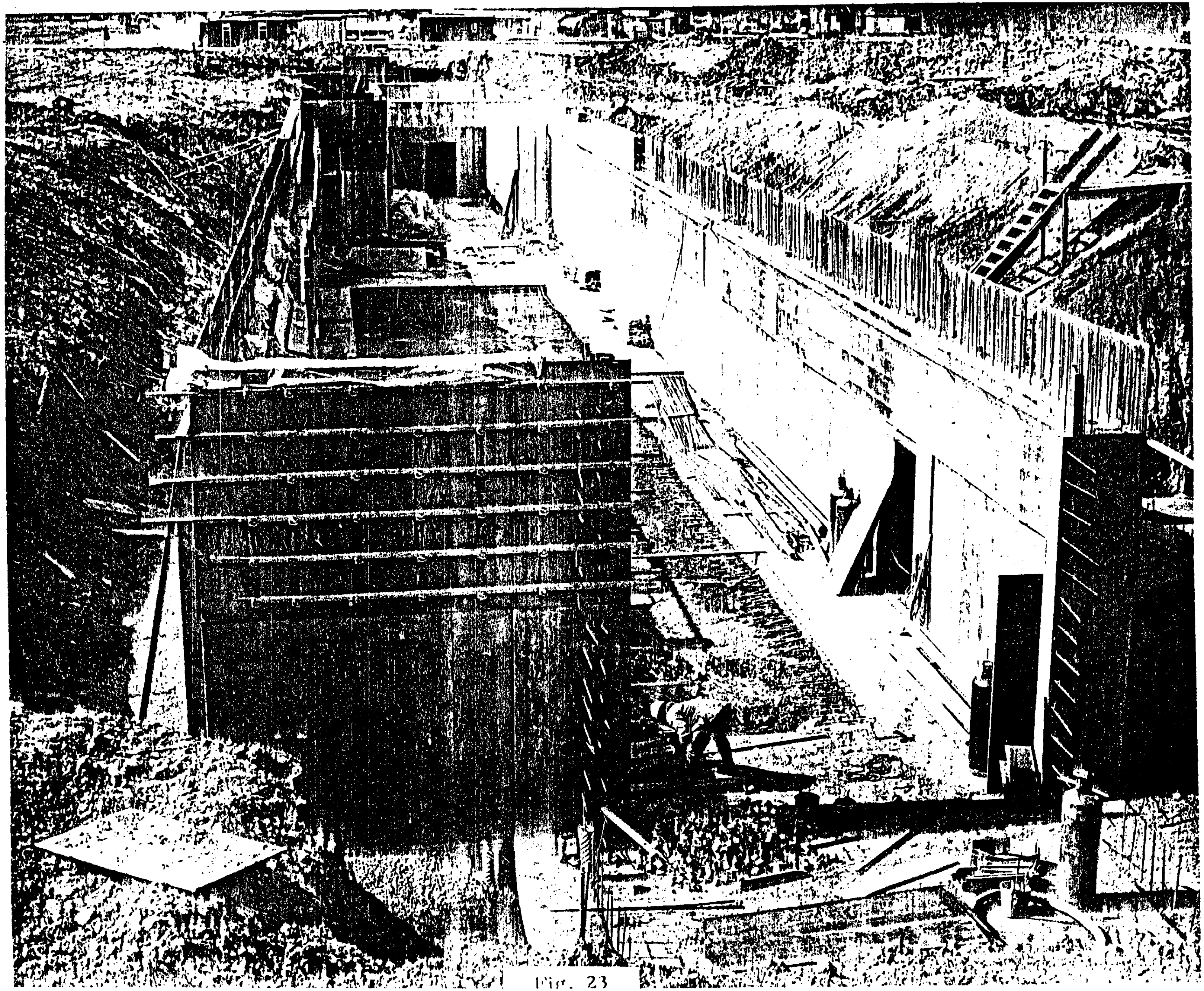


Fig. 23

Meson Area Beams

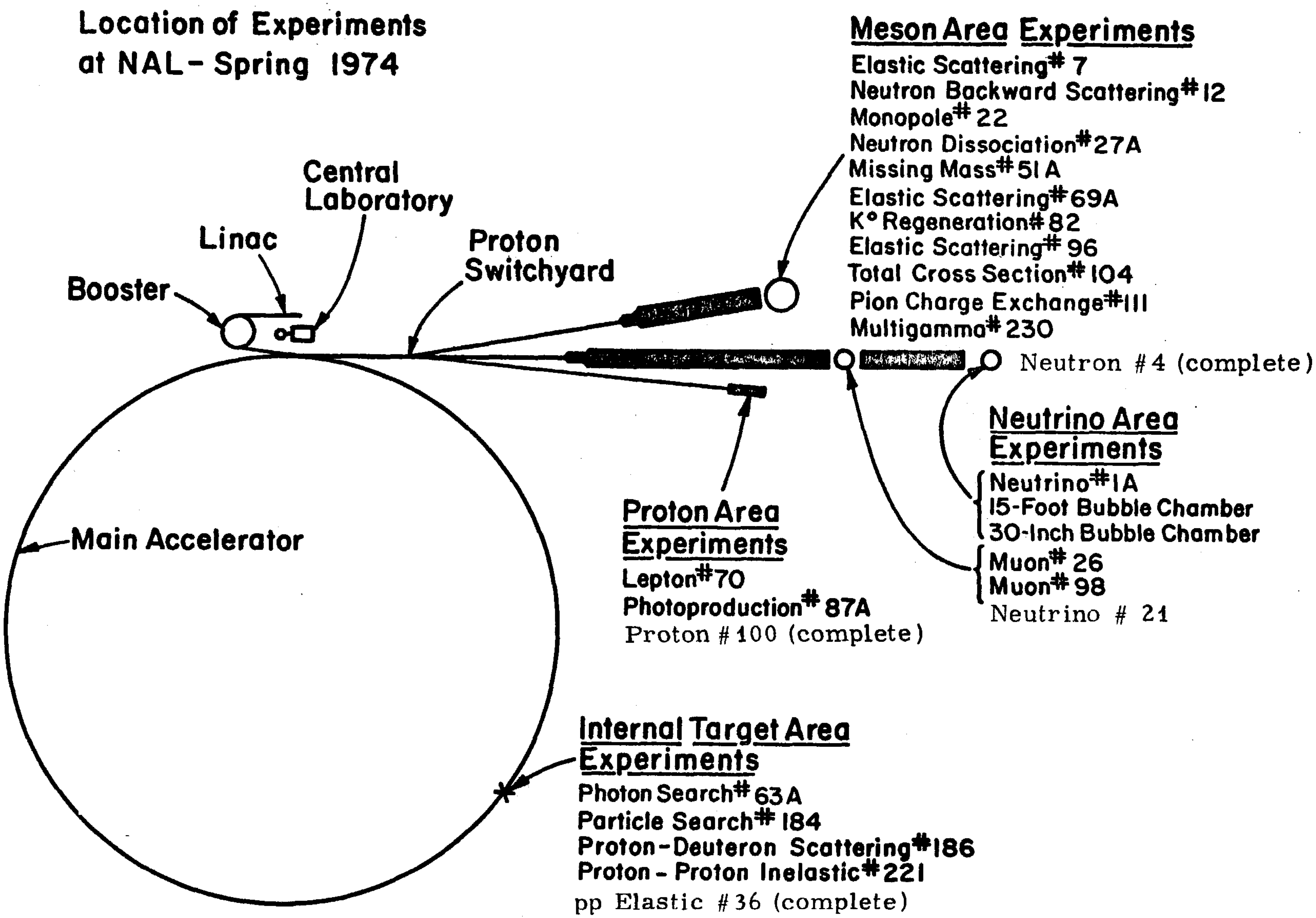
Beam	Production Angle mrad	Maximum Momentum GeV/c	Solid Angle μsr	Momentum Acceptance $\Delta p/p$	Approx. Flux per 10^{13} Interacting Protons at 300
M1 π, K, High Energy $\bar{p}$, p	~~3.91~~ 3.6	~~200~~ 280	2.0	$\pm 0.1\% \rightarrow \pm 2.0\%$	10^7 π at 150 GeV
M2 (Hyperon) Diffracted Proton	~~175~~ 1.0	300	0.22	$\pm 0.1\% \rightarrow \pm 1.4\%$	10^{10} p at 200 GeV
M3 Neutron Beam	~~175~~ 1.0		Variable		10^8 /cm^2
M4 K° Beam	~~6.5~~ 7.25		Variable		10^6 /cm^2
M5 Test Medium Energy	20.0	50	6.2	$\pm 0.05\% \rightarrow \pm 0.5\%$	10^6 π at 50 GeV
M6 High Energy High Resolution Single Arm Facility Multiple Spectrometer	3.05	200	1.34	$\pm 0.014\% \rightarrow \pm 1.0\%$	10^7 π at 100 GeV

Fig. 24

SPECIFIC CONCEPTS FOR EACH AREA AND THE BEAMS

	ITA	MA	NA	PA
proton energy:	30-500	300	400+	500
typical proton limit intensity per pulse:	$<10^{10}$ interactions	5×10^{12}	10^{13}	$10^{10}+10^{13}$
intended use of the experimental facility:	small electronic detectors inside main ring using circulating beam	electronic experiments in hadron beams	15' and 30" bubble chambers and large electron detectors in muon and neutrino	electronic experiments using extracted proton beam directly
scope of the facility:	makes use of multiple turn beam of increasing energy in two internal targets	general purpose secondary beams containing one target with 5-6 beams	specialized ν,μ and hadron beams for the detectors using two targets with 3+ beams	uses protons directly in transmission or production targets using 3 target stations
number of secondary beams:	none	3-4 charged 2 neutral	2+charged 1 neutral	1 photon 1 neutral
types of particles:	protons	neutrons diff. protons K°'s high energy high energy, high resolution test beam	hadrons for bubble chambers μ's for counters ν's for counters and bubble chambers high energy pions	protons electrons photons
number of detector stations: (eventually)	4-6	~10	6	7+

Fig. 25



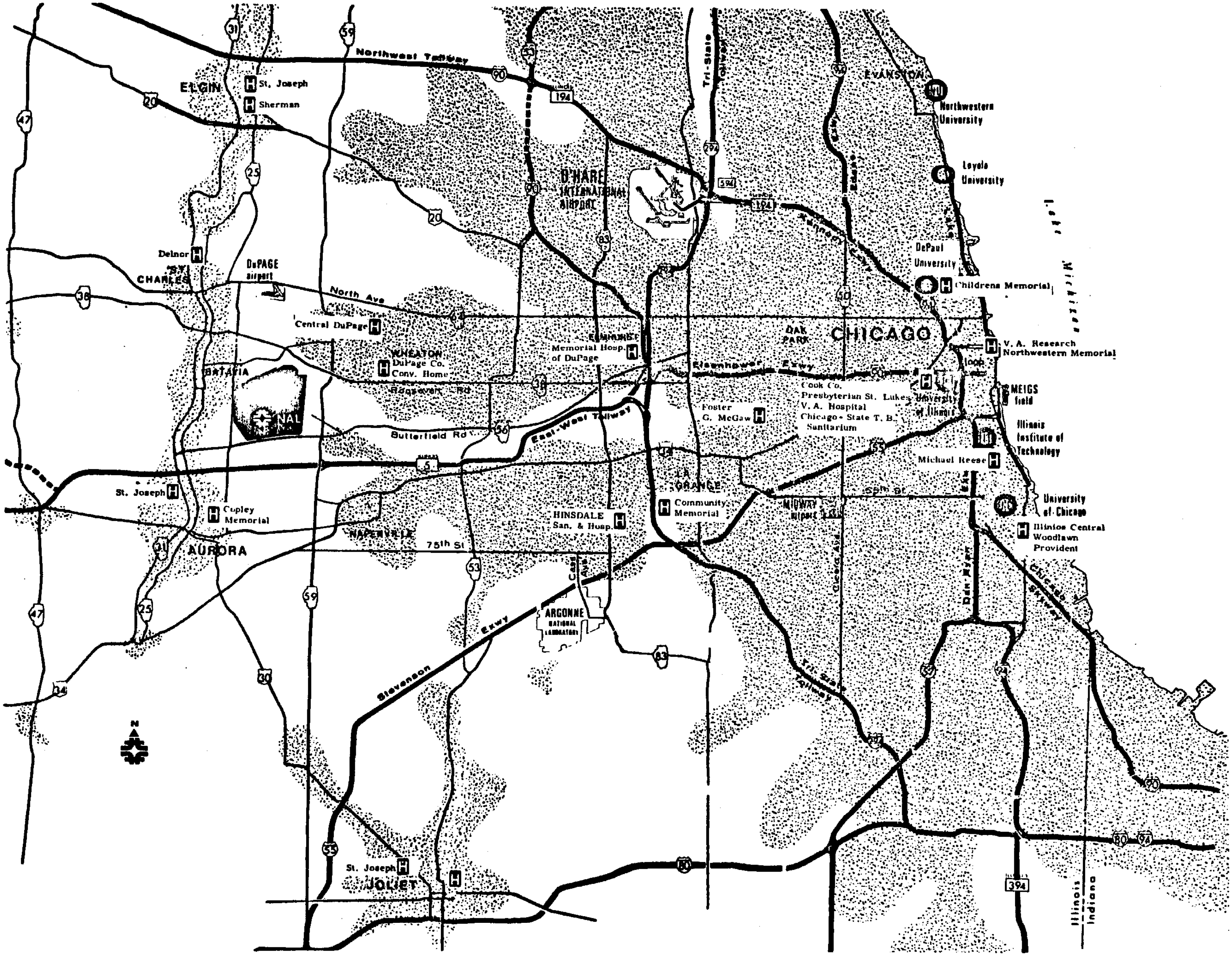
Location of Experiments
at NAL - Spring 1974
Meson Area Experiments
Elastic Scattering # 7
Neutron Backward Scattering # 12
Monopole # 22
Neutron Dissociation # 27A
Missing Mass # 51 A
Elastic Scattering # 69A
K° Regeneration # 82
Elastic Scattering # 96
Total Cross Section # 104
Pion Charge Exchange # 111
Multigamma # 230
Central
Laboratory
Linac
Booster
Proton
Switchyard
Neutron # 4 (complete)
Neutrino Area
Experiments
Neutrino # 1A
15-Foot Bubble Chamber
30-Inch Bubble Chamber
Muon # 26
Muon # 98
Neutrino # 21
Proton Area
Experiments
Lepton # 70
Photoproduction # 87A
Proton # 100 (complete)
Main Accelerator
Internal Target Area
Experiments
Photon Search # 63 A
Particle Search # 184
Proton-Deuteron Scattering # 186
Proton - Proton Inelastic # 221
pp Elastic # 36 (complete)

Fig. 26

List of Experiments Included on the NAL Monthly Experimental Program Plan

Exp. Number	Short Title	Spokesman
1A	Neutrino	D. Cline
2B	30-Inch Hybrid	G. Smith
3	Monopole	P. Eberhard
4	Neutron Cross Section	M. Longo
7	Elastic Scattering	D. Meyer
8	Neutral Hyperon	L. Pondrom
12	Neutron Backward Scattering	N. Reay
21A	Neutrino	B. Barish
22	Monopole	G. Collins
26	Muon	K.W. Chen
27A	Neutron Dissociation	J. Rosen
31A	15-Foot Anti-Neutrino/H_2	M. Derrick
45A	15-Foot Neutrino/H_2	F. Nezrick
51A	Missing Mass	E. von Goeler
63A	Photon Search	J. Walker
69A	Elastic Scattering	J. Sandweiss
70	Lepton	L. Lederman
76	Monopole	R. Carrigan
81A	Nuclear Chemistry	M. Weisfield
82	K Zero Regeneration	V. Telegdi
87A	Photoproduction	W. Lee
95A	Photon Search	B. Cox
96	Elastic Scattering	D. Ritson
98	Muon	R. Wilson
100A	Particle Search	J. Cronin
104	Total Cross Section	R. Cool
108	Beam Dump	M. Awschalom
110A	Multiparticle	J. Pine
111	Pion Charge Exchange	A. Tollestrup
138	30-Inch $p\text{-}p$ @ 400	J. VanderVelde
143A	30-Inch π^--p @ 300	G. Kalbfleisch
154	30-Inch Hybrid	I. Pless
155	15-Foot EMI Test	V. Peterson
161	30-Inch $p\text{-}p$ & Ne @ 300	J. Mapp
163A	30-Inch π^--p & Ne @ 100 or 200	W. Walker
177A	Proton-Proton Elastic (test)	J. Orear
178	Multiplicities	W. Busza
184	Particle Search	A. Mann
186	Proton-Deuteron Scattering	A. Melissinos
221	Proton-Proton Inelastic	P. Franzini
228	30-Inch p-p @ 60	T. Ferbel
229	Detector Development	L. Yuan
234	15-Foot Engineering Run	F. Huson
257	Muon	T. Kirk
261	Detector Development	C.L. Wang
262	Neutrino	B. Barish

Fig. 27



Northwest Tollway
ELGIN
St. Joseph
Sherman
EVANSTON
Northwestern University
Loyola University
O'HARE INTERNATIONAL AIRPORT
Tri-State Tollway
Kennedy Exwy
DePaul University
Childrens Memorial
Delnor
ST. CHARLES
DuPAGE airport
North Ave
Central DuPage
WHEATON
DuPage Co. Conv. Home
Memorial Hosp. of DuPage
OAK PARK
CHICAGO
V. A. Research
Northwestern Memorial
BATAVIA
Roosevelt Rd
Eisenhower Exwy
Cook Co.
Presbyterian St. Lukes
V. A. Hospital
Chicago - State T. B. Sanitarium
University of Illinois
MEIGS field
NAL
Butterfield Rd
East-West Tollway
Foster G. McGaw
Illinois Institute of Technology
Michael Reese
St. Joseph
Copley Memorial
LA GRANGE
Community Memorial
MIDWAY airport
University of Chicago
Illinois Central
Woodlawn
Provident
HINSDALE San. & Hosp.
NAPERVILLE
75th St
AURORA
ARGONNE NATIONAL LABORATORY
Stevenson Exwy
Dan Ryan
Chicago Skyway
Tri-State Tollway
St. Joseph
JOLIET
Illinois
Indiana
N